GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: 9/12/80

Project Title: SEEKER TARGET SYSTEM INVESTIGATION

S

Project No: A-2692

Project Director: Mr. G. R. Loefer

Sponsor: USAF/AFSC ROME AIR DEVELOPMENT CENTER; GRIFFISS AFB, NY 13441

Agreement Period: From 7/8/80 Until ~~4/7/81~~ ~~7/7/81~~ 9/7/81 (R&D PERF. PERIOD)

Type Agreement: CONTRACT NO. F30602-80-C-0233

Amount: $91,041 (PARTIALLY FUNDED FOR $35,000 THROUGH 9/30/80)

Reports Required: MONTHLY R & D STATUS REPORTS; FINAL TECHNICAL REPORT

Sponsor Contact Person (s):

Technical Matters

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ROME AIR DEVELOPMENT CENTER
GRIFFISS AFB, NY 13441

Contractual Matters
(thru OCA)

MR. THOMAS A. BRYANT
ONR RESIDENT REPRESENTATIVE
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ATLANTA, GA 30332

Defense Priority Rating: DO-A7 UNDER DMS REG 1

Assigned to: EML/EOD (~~School~~/Laboratory)

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- Other

Rec'd Sept

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 4/16/82

Project Title: Seeker Target System Evaluation

Project No: A-2692

Project Director: G. R. Loefer

Sponsor: USAF/AFSC - RADC

Effective Termination Date: 9/7/81

Clearance of Accounting Charges: 10/7/81

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice and Closing Documents
- [ ] Final Fiscal Report
- [x] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other __________

Assigned to: EML (School/Laboratory)

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Project File
Other __________

FORM OCA 10:781

MONTHLY PROGRESS REPORT NO. 1

8 July 1980 to 1 August 1980

Seeker Target System Investigation

by

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force AFSC

Rome Air Development Center

Griffiss AFB, N.Y. 13441

Prepared by

Georgia Institute of Technology

Engineering Experiment Station

Atlanta, Georgia 30332

September 12, 1980

Work Performed This Period

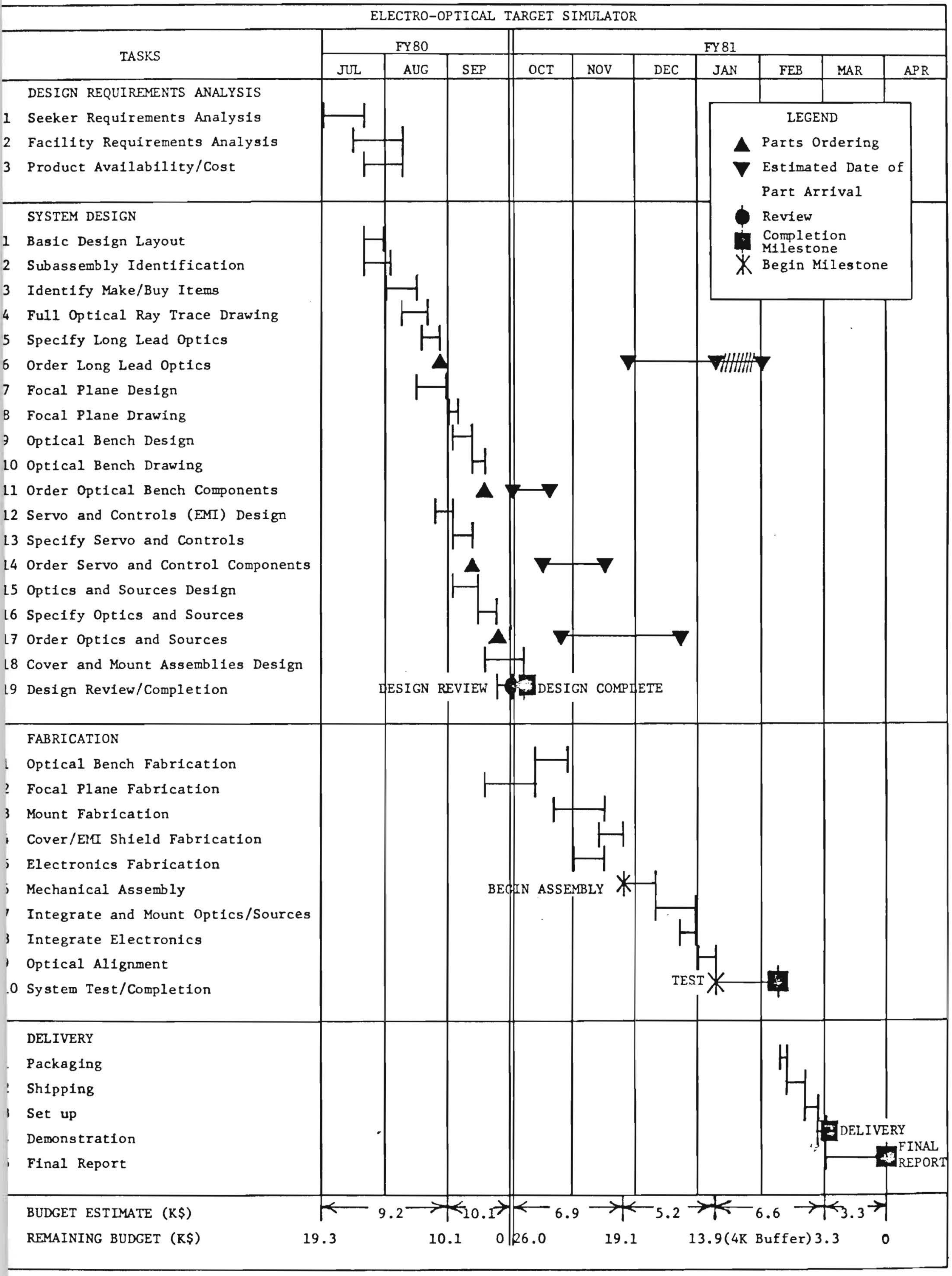
Project personnel visited RADC to examine facility for which the Seeker Target Simulator (STS) must be designed. Physical clearances and dimensions, remote control location, power availability and facility configuration were examined. In addition, assembly support equipment was examined to estimate component or subsystem weight and size limits.

Previous work (G. T. project A-2366 and proposal was reviewed and product availability search was begun. Seeker requirements were reviewed so that design trades could be made later. In addition, several alternative design concepts, both old and new, were considered to give a background to determine driving factors for each concept. Limits and advantages for all concepts were also considered.

Finally, a schedule of detailed task completion was generated and is included in this report. The schedule details task completion, as well as indicates significant performance and fiscal milestones.

Financial Status

No financial status information for the period reported was available. This information will be provided in the next progress report.


ELECTRO-OPTICAL TARGET SIMULATOR
TASKS
FY80
FY81
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
DESIGN REQUIREMENTS ANALYSIS
1 Seeker Requirements Analysis
2 Facility Requirements Analysis
3 Product Availability/Cost
SYSTEM DESIGN
1 Basic Design Layout
2 Subassembly Identification
3 Identify Make/Buy Items
4 Full Optical Ray Trace Drawing
5 Specify Long Lead Optics
6 Order Long Lead Optics
7 Focal Plane Design
8 Focal Plane Drawing
9 Optical Bench Design
10 Optical Bench Drawing
11 Order Optical Bench Components
12 Servo and Controls (EMI) Design
13 Specify Servo and Controls
14 Order Servo and Control Components
15 Optics and Sources Design
16 Specify Optics and Sources
17 Order Optics and Sources
18 Cover and Mount Assemblies Design
19 Design Review/Completion
DESIGN REVIEW
DESIGN COMPLETE
FABRICATION
1 Optical Bench Fabrication
2 Focal Plane Fabrication
3 Mount Fabrication
4 Cover/EMI Shield Fabrication
5 Electronics Fabrication
6 Mechanical Assembly
7 Integrate and Mount Optics/Sources
8 Integrate Electronics
9 Optical Alignment
10 System Test/Completion
BEGIN ASSEMBLY
TEST
DELIVERY
1 Packaging
2 Shipping
3 Set up
4 Demonstration
5 Final Report
DELIVERY
FINAL REPORT
LEGEND
Parts Ordering
Estimated Date of Part Arrival
Review
Completion Milestone
Begin Milestone
BUDGET ESTIMATE (K$)
9.2
10.1
6.9
5.2
6.6
3.3
REMAINING BUDGET (K$)
19.3
10.1
0
26.0
19.1
13.9(4K Buffer)
3.3
0

MONTHLY PROGRESS REPORT NO. 2

1 August to 1 September 1980

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233
Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFb, N.Y. 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

10 September, 1980

Work Performed This Period

The proposed design concept and alternatives were fully investigated. The result is that the proposed design is the best compromise at the current time. A few changes in mirror placement were made, eliminating the need for the 6" fold mirror proposed. The orientation of the large output mirror was changed to permit the use of a 24" diameter mirror instead of the 28" mirror proposed. This was necessary as 24" is a significant break point in standard glass stock sizes and price.

The current design meets resolution requirements for scan angles of $\pm 1^{\circ}$. With the 16" diameter primary, this results in an unvignetted spot diameter of 2.5" at 24 feet. This is adequate for the smallest seekers. Larger seekers can be tested at this range, because vignetting degrades beam irradiance continuously and symmetrically in the radial direction. However, this requires more precise alignment in order to avoid amplitude modulation produced by displacement of the scan center from seeker boresight. Also, a full 4" spot diameter is still obtained 18 feet, which should be adequate for the larger seekers.

Although the system has been designed to meet resolution requirements at $\pm 1^{\circ}$, clearances have been allowed to permit scan angles up to $\pm 1.5^{\circ}$ with degraded performance. Also, the maximum target diameter has been reduced to 0.5° from 2.0° due to physical clearance problems in the focal plane periscope. However, it is still felt this target diameter will be adequate for testing seeker performance with extended targets.

Financial Status as of 31 July 1980

	Budget	Expended	Encumbered	Free Balanc
Personal Services	12,843	2,211.32	—	10,631.68
Retirement	1,345	245.68	—	1,099.32
Materials and Supplies	10,692	0	0	10,692.00
Travel	745	660.00	180.00	-95.00
Overhead	9,375	1,614.26	—	7,760.74
Total	35,000.00	4,731.26	180.00	30,088.7

MONTHLY PROGRESS REPORT NO. 3

1 September to 1 October 1980

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC

Rome Air Development Center

Griffiss AFB, N.Y. 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

13 January, 1981

Work Performed This Period

The system design was finalized and work was begun on producing layout and detail drawings in order to begin fabrication. During the final design stages, the design was changed to take advantage of the simulator geometry to reduce the required size of the output mirror from 24" to less than 16". This produces vignetting in the output beam, but the seeker is never in the blocked portion of the beam. This change does not affect the spot size at the seeker.

Also during final design, the scanning periscope was reconfigured to greatly reduce the required gear size. This was required since large diameter, high precision gears involve considerable expense (greater than $20K) and long deliveries (longer than 20 weeks). As it is, the highest precision gears are the limiting component in both position accuracy and position readout sensitivity.

At the end of the month materials orders were approximately 30% complete.

Financial Status as of 31 August 1980

	Budget	Expended	Encumbered	Free Balance
Personal Services	12,843.00	4,161.75	---	8,681.25
Retirement	1,345.00	442.57	---	902.43
Materials and Supplies	10,692.00	0.00	56.64	10,635.36
Travel	745.00	838.83	0.00	-93.83
Overhead	9,375.00	3,038.07	---	6,336.93
TOTAL	35,000.00	8,481.22	56.64	26,462.14

MONTHLY PROGRESS REPORT NO. 4

1 October to 1 November 1980

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, N.Y. 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

13 January 1981

Work Performed This Period

During this period, specific components were located and ordered. Of particular importance was the location of a motor and controller which would provide sufficient torque over a range of speeds from 5 to 7500 rpm (a ratio of 1500:1). This exceeds the system requirements. This allows the design of the drive gears to provide additional low speed performance, which also assures good torque margin at the minimum system requirements. Also, the controller specifications on speed regulation at the low speed range are a factor of 50 better than the design goal.

A review of the program was presented to RADC on October 29.

Financial Status as of 30 September, 1980

	Budget	Expended	Encumbered	Free Balance
Personal Services	12,843.00	6,933.12	---	5,909.88
Retirement	1,345.00	701.92	---	643.08
Materials and Supplies	10,692.00	56.64	390.00	10,245.36
Travel	745.00	838.83	0.00	-93.83
Overhead	9,375.00	5,061.17	---	4,313.83
TOTAL	35,000.00	13,591.68	390.00	21,018.32

MONTHLY PROGRESS REPORT NO. 5

1 November to 1 December 1980

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, N.Y. 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

13 January, 1981

Work Performed This Period

Mechanical drawings and optical encoder circuit layouts were completed. Fabrication of the focal plane assembly, and focal plane plates was begun and significant progress was made before the month's end. Orders for parts were nearly complete (approximately 95%). Many of the components which were ordered earlier have arrived, including the arclamp power supply, and some of the precision gears. Several components have quoted delivery times which may cause delays to the project schedule. The optical shaft encoder is known to have such a delay in delivery. The large primary and secondary mirrors, the mirror mounts and the blackbody source may also have delivery problems.

Financial Status as of 31 October, 1980

	Budget	Expended	Encumbered	Free Balance
Personal Services	12,843.00	10,330.49	---	2,512.51
Retirement	1,345.00	910.36	---	434.64
Materials and Supplies	10,692.00	61.64	12,563.00	-1,932.64
Travel	745.00	838.83	0.00	-93.83
Overhead	9,375.00	7,541.25	---	1,833.75
TOTAL	35,000.00	19,682.57	12,563.00	2,754.43

MONTHLY PROGRESS REPORT NO. 6

1 December 1980 to 1 January 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, N.Y. 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

13 January, 1981

Work Performed This Period

Fabrication of all mechanical pieces which were to be done by Georgia Tech has been completed. This early fabrication completion has put Georgia Tech back on schedule. However, none of the major optical components have been received. Assembly must await arrival of these components. Vendors have been contacted and promised shipment is imminent. However, in the interim, project staffing has been reduced to minimize the costs due to the schedule stretch out. Several major components have arrived, including the blackbody source, laser components, drive gears, motor, motor controller, motor speed circuitry and the neutral density filters. All components have been ordered at this time.

During the month, full funding was received and is reflected in the financial status.

Financial Status as of 30 November 1980

	Budget	Expended	Encumbered	Free Balance
Personal Services	33,444.00	13,939.21	---	19,504.79
Retirement	3,503.00	1,224.78	---	2,278.22
Materials & Supplies	27,740.00	511.77	20,748.45	6,479.78
Travel	1,940.00	838.83	0.00	1,101.17
Overhead	24,414.00	10,175.62	---	14,238.38
TOTAL	91,041.00	26,690.21	20,748.45	43,602.34

MONTHLY PROGRESS REPORT NO. 7

1 January 1981 to 1 February 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

2 February 1981

Work Performed This Period

During this month, all of the pieces in the scanner gear train, not including the optical shaft encoder, were available for assembly. The scanner was assembled and tested. The motor performs extremely well, with a wider dynamic range than required by the design goals. The motor drives well from approximately 2 rpm to well over 8300 rpm. With a 1 degree target angle, this corresponds to a tangential velocity of from 0.6 mrad/sec to 36 deg/sec, or over 1080:1 range. Speed regulation cannot be thoroughly checked until the shaft encoder is installed, but the digital display which is part of the motor circuit indicates that speed regulation is better than $\pm 1\%$.

There is currently a problem with the large gear which has had the optical clearance hole bored through its center. There appears to be eccentricity in this gear movement, due either to misalignment or gear deformation. This causes a change in tone of gear noise, and a slight motion of the secondary gear and shaft. This problem was anticipated and three alternatives are possible:

1) Attempt to bore a spare gear. This may or may not be successful, as the source of the deformation is likely to be stress relief in the gear caused by the creation of the large diameter bore.

2) Attempt to adjust the current gear to offset the deformation. This is a limited possibility, since the runout is less than 1.5 mils. Any manual adjustment procedures would have difficulty doing much better.

3) Leave the gear train as is. For now, this appears to be the best action, as the motor seems able to regulate well, in spite of the uneven load. When the optical shaft encoder is installed, an accurate assessment on speed stability can be made and options 1 and 2 will still be available.

In parts procurement, the large mirror mounts were received, as well as the arclamp housing and most of the electronic components for the shaft encoder circuitry. As stated previously, the motor and speed readout have been assembled and tested. Both the blackbody source and the arclamp have also been tested and found to perform satisfactorily.

Financial Status as of December 31, 1980

	Budget	Expended	Encumbered	Free Balance
Personal Services	$33,444.00	$ 6,234.80	$ 0.00	$17,209.20
Retirement	3,503.00	1,448.43	0.00	2,054.57
Materials & Supplies	27,740.00	1,303.98	20,194.95	6,241.07
Travel	1,940.00	838.83	0.00	1,101.17
Overhead	24,414.00	11,851.40	0.00	12,562.60
TOTAL	$91,041.00	$31,677.44	$20,194.95	$39,168.61

MONTHLY PROGRESS REPORT NO. 8

1 February 1981 to 1 March 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U. S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

18 March 1981

Work Performed This Period

In last month's progress report, an inadvertent error was made in the quotation of the motor dynamic range. Although the speeds were correct, the actual dynamic range is 4150:1 instead of 1080:1.

During this month, the optical shaft encoder was installed in the gear train. The line driver electronics, which amplify the encoder output signals from transmission to the control room, were constructed and tested. Wiring of the decoder circuit was completed and component installation and check out was begun. At this point, all signals appear to be very satisfactory and no major problems are anticipated.

All components except the large diameter mirrors and one precision gear have been received. The mirrors are still encountering considerable delays in delivery. According to the vendor, the most recent problem has been with severe contamination of the reflective coatings. They have tried their usual coating source twice and have failed to get a satisfactory coating. The mirror vendor has since shipped the mirrors to a secondary source. This source has promised coating by March 16, but the optical vendor believes it will take longer, based on past experience. While awaiting delivery of these mirrors, a temporary setup using an 8 in. diameter, F/4 mirror will be conducted to approximate the final optical configuration.

The last of the gears was received. However, the vendor set a lower quality gear than ordered. The gear has been returned, pending shipment of the proper gear. With the exception of the above three items (2 mirrors and a gear), all other parts have been received.

Financial Status as of January 31, 1981

	Budget	Expended	Encumbered	Free Balance
Personal Services	$33,444.00	$17,471.75	$ 0.00	$15,972.25
Retirement	3,503.00	1,550.72	0.00	1,952.28
Materials and Supplies	27,740.00	11,133.03	12,374.05	4,232.92
Travel	1,940.00	838.83	0.00	1,101.17
Overhead	24,414.00	12,754.37	0.00	11,659.63
TOTAL	$91,041.00	$43,748.70	$12,374.05	$34,918.25

MONTHLY PROGRESS REPORT NO. 9

1 March to 1 April 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U.S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

9 April 1981

Work Performed This Period

During this month, the electronic circuit to decode the scan position and rate was wired and checked out. Both outputs were wired and debugged, first using an oscilloscope and then by actually reading the output latches with a microcomputer. Although several minor problems were encountered, both in design and wiring, all have been corrected at this time.

As of this writing, none of the parts listed as missing in the last report have been delivered. On March 27, I was able to contact the optical vendor. He stated at that time that both mirrors should have been coated and would be shipped to him from the coater on the following Monday. At my last contact, the primary was to be shipped by truck to the vendor, this being the fastest means available. Thus, the mirrors should have been received by Tuesday afternoon or Wednesday morning. The vendor required 1 1/2 days for testing and another day for packing before shipment via UPS Blue Label service to Georgia Tech. That would put expected delivery on or about April 6. Since the system has been checked out with the 8 inch system and found to perform correctly, testing on the larger mirrors can begin as soon as they're mounted.

Financial Status as of February 29, 1981

	Budget	Expended	Encumbered	Free Balance
Personal Services	$ 33,444.00	$ 19,534.58	$ 0.00	$ 13,909.42
Retirement	3,503.00	1,674.11	0.00	1,828.89
Materials & Supplies	27,740.00	12,705.05	11,875.31	3,159.64
Travel	1,940.00	838.83	0.00	1,101.17
Overhead	24,414.00	14,260.24	0.00	10,153.76
TOTAL	$91,041.00	$49,012.81	$11,875.31	$30,152.88

MONTHLY PROGRESS REPORT NO. 10

April 1, 1981 to May 1, 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U.S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

May 15, 1981

Work Performed This Period

The mirrors which were expected to arrive early this month have still not arrived. Several reasons were given by the optical vendor. First, the coating house to which the primary mirror was shipped originally quoted 10-15 days. After 2 weeks, they unilaterally and without notification to anyone decided the coating was unacceptable and held the mirror for recoating. Secondly, after the decision to hold the mirror, nothing was done to the mirror for nearly 1 1/2 weeks, again without notification. Third, once the mirror was received by the vendor, he took 3 days for testing and packaging instead of the original 1 to 1 1/2 days estimate. Then the mirror was shipped via UPS Blue Label, which the vendor admitted, after shipment, usually took 3 to 4 days instead of the 24 to 48 hours originally given. Without ever reaching Georgia Tech, the package was returned to the vendor damaged, one week later. The vendor then promised to ship the slightly damaged mirror the next day via Federal Express on Tuesday, April 28. As has since been learned, the mirror was not actually shipped until Friday, May 1 and received at Georgia Tech on Tuesday, May 5. Also, the mirror received was undamaged. The vendor explained that this was a "sister" mirror, cut from the same tool to exactly the correct focal length. After a few quick measurements, the mirror does appear to have a focal length which is sufficient for the simulator design. As of last contact, the flat mirror has not been coated by the vendor's local source and was shipped to the coater who did the primary. Delivery date is unknown, considering past performance on these two entities.

Also, during the month, the system was demonstrated to the technical monitor and a guest.

Financial Status as of March 31, 1981

	Budget	Expended	Encumbered	Free Balance
Personal Services	$33,444.00	$23,029.65	.00	$10,414.35
Retirement	3,503.00	2,000.41	.00	1,502.59
Materials & Supplies	27,740.00	17,822.79	6,527.60	3,389.61
Travel	1,940.00	838.83	.00	1,101.17
Overhead	24,414.00	16,811.64	.00	7,602.36
TOTAL	$91,041.00	$60,503.32	$6,527.60	$24,010.08

MONTHLY PROGRESS REPORT NO. 11

1 May to 1 June 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U.S. Air Force, AFSC
Rome Air Development Center
Griffiss AFB, NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

June 17, 1981

Work Performed This Period

As reported last month, the primary mirror was finally received on May 5. The mirror was received in good condition. Although the vendor claims the mirror exactly meets specifications with an 80 inch focal length, two independent tests have shown that the focal length is between 78.5 and 78.75 inches. The first measurement is from a Ronchi null test which locates the mirror center of curvature. The focal length is half the distance between the mirror and the center of curvature. The second figure was obtained using an autocollimater. The autocollimator is a highly accurate and calibrated telescope. The telescope can be exactly set for infinity focus and by using the eyepiece reticle as a reference, the primary can be focused to produce an image at infinity. The focal length is the distance between the primary and the focal plane. Since these two tests are distinctly different methods but yield results in close agreement, the primary is probably near 78.5 in focal length. However, this discrepency is less than 2%, which is within standard tolerences. This difference has no effect on the performance of the system.

Also using the autocollimator, the actual images produced by the mirror are of excellent quality. The autocollimator aperture is 4 inches in diameter, very close to the size of many seekers. Over this smaller aperture, the primary produces an image with an estimated resolution of 0.05 to 0.1 mrad resolution. The goal was 1.0 mrad. The primary reason for this difference is that the autocollimator is not looking at the full 16 inch aperture at any one time, which always improves performance. The next test will be to measure the magnitude of aberrations of the primary which introduce deviations from a circular path.

Since the large flat mirror had still not been coated as of May 15, a front surface, 16 inch square mirror was ordered and received. The mirror is only 6 mm thick, so it is not expected to be able to maintain the required surface accuracy. However the mirror does appear to be of good enough quality to act as a temporary substitute for the larger mirror. This has allowed setup of the entire optical train to check optical alignment and mechanical clearances. With the full optical layout, an unvignetted spot diameter of 3 inches was measured at 26 feet range and $\pm 1^{\circ}$ scan. This approximates the actual setup in the chamber with a maximum range of 24 feet.

Work on the rack mounted electronics package was nearing completion at the end of the month. The power supply for the arclamp has been successfully repackaged so that only the blackbody controller will be outside the electronics package, in its own rack mounted box. Both boxes are standard 19" wide, one is 3.5" high and the other is 7" high.

Separate quick disconnects are provided for the motor and arclamp. Three separate RS-232 connectors are associated with the shaft encoder circuit. One is for input from the STS. The other two are separate connections for the 16 bit outputs for position and rate, as well as ground and handshaking signals. Three BNC type connections on the front panel provide test points for monitoring the encoder inputs: counts clockwise, counts counterclockwise and zero index. These test points will provide a quick check of proper optical encoder operation.

Financial Status as of May 31, 1981

	Budget	Expended	Encumbered	Free Balance
Personal Services	$33,444.00	$25,597.13	.00	$7,846.87
Retirement	3,503.00	2,259.14	.00	1,243.86
Materials & Supplies	27,740.00	17,849.14	6,429.90	3.460.96
Travel	1,940.00	839.83	.00	1,101.17
Overhead	24,414.00	18,685.90	.00	5,728.10
TOTALS	$91,041.00	$65,230.14	$6,429.90	$19,380.96

A-2692

MONTHLY PROGRESS REPORTS NOS. 12 and 13

1 June to 1 August 1981

SEEKER TARGET SYSTEM INVESTIGATION

Gene R. Loefer

Contract No. F30602-80-C-0233

Project No. A-2692

Prepared for

U.S. Air Force, AFSC
Rome Air Development Center
Griffis AFB. NY 13341

Prepared by

Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

August 3, 1981

Work Performed This Period

During this period, the electronics package was completed and re-tested. All electronics and power supplies were functioning properly.

Due to inordinate delays in the delivery of the 16 inch diameter circular flat, the order was cancelled. A fifteen inch square flat was found to replace the circular mirror. The square was mounted with the diagonal corners in the horizontal and vertical positions respectively, to provide the maximum clear aperture. Upon receipt of the flat, the accuracy tests were repeated. It was determined that the errors observed with the thin flat, were actually in the observing optics.

The total system was then tested using a different method. A camera was placed at a distance from the system so that the image of the focal plane up to $\pm 1^{\circ}$ from scan center just filled the entire primary aperture. Several targets were placed in the focal plane to give a measure of the total system aberration. Each of the targets was photographed. When the resulting images were compared with the originals, a direct measure of system performance was obtained. The static combined resolution and distortion was found to be less than 0.1 mrad. The dynamic runout was found to be 0.9 mrad, which compares well with the design goal of 0.8 mrad.

Also during this period, the dust and light protective covers were designed and fabricated. Before delivery, these covers must be painted, and have an exit aperture cut in the proper place. All focal plane pieces must be painted and light shields designed. Finally, shipping crates must be designed and built.

FINANCIAL STATUS AS OF JULY 31, 1981

	Budget	Expended	Encumbered	Balance
Personal Services	$33,444.00	$30,755.12	--	$2,718.88
Retirement	3,503.00	2,642.98	--	860.02
Materials & Supplies	27,740.00	20,250.60	950.00	6,539.40
Travel	1,940.00	838.83	--	1,101.17
Overhead	24,414.00	22,452.58	--	1,961.42
Totals:	$91,041.00	$76,910.11	950.00	$13,180.89

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the design and construction of a target source simulation breadboard, the seeker target system (STS). The report describes system performance and provides instructions for system setup and operation. Also described and expressly stated are all the calculations required to operate the STS.

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SUMMARY

This report documents the design, fabrication, and test of a seeker targeting system. The objective of this effort was to investigate and fabricate a target motion simulator and associated infrared, electro-optical and laser sources for implementation in the Electromagnetic Compatibility Analysis Facility (EMCAF) at the Rome Air Development Center. The effort resulted in a breadboard model to be utilized as a target simulator to exercise various guided bomb/missile seeker units while they are simultaneously being irradiated with high power RF energy. The breadboard model will be used in the EMCAF to determine the susceptibility of Air Force weapon systems to the electromagnetic environment in which they operate. The design in an intense electromagnetic environment, the physical size of the systems under test and the requirement that the system project a collimated image to the seeker. It was also constrained by stringent controls of such key characteristics as target angular size, angular rate, position and jitter. A primary goal of the breadboard design was to produce a system that would be as close to a fully operational simulator as possible. This goal has, in fact, been accomplished with the final design meeting or exceeding nearly all of the critical design goals.

Table of Contents

1.0 Introduction

This report is intended to document the detailed results of the design and construction of a target source simulation breadboard. The seeker target system (STS) is designed to be used to test infrared, laser, and electro-optical guided missiles in the Rome Air Development Center (RADC) anechoic test chamber. In this test a missile will be subjected to RF radiation to determine its electromagnetic interference (EMI) susceptibility. In particular, the tests will attempt to determine the conditions which cause loss of missile control as a function of target parameters. In these tests, the simulator will provide a target upon which to lock the missile seeker and control gimbal pointing angle and track rate. The objective of this effort is to validate the design concept through the construction of a breadboard system.

A primary goal of the breadboard design was to produce a system that would be as close to a fully operational simulator as possible. This goal has in fact been accomplished, with the final design meeting or exceeding nearly all critical design goals.

2.0 Design

The STS design was actually begun under a previous study contract (F30602-78-C-0120). Under this contract, simulator requirements were established after study of seeker characteristics, anechoic chamber restrictions and design cost/performance analyses. The result of this study was a conceptual design and cost estimate. Under the current contract, the conceptual design and design goals were fully reexamined, a detailed design was executed, and a breadboard simulator was constructed.

Electro-optic seekers and trackers are designed to operate against distant targets. Under such conditions objects are effectively located at infinity, i.e., light from each point on the object is collimated. The seeker optics therefore image targets in the system focal plane. If objects are too close, the image is located a significant distance behind the seeker focal plane and performance is seriously degraded. Therefore an E-O target simulator must present a collimated image to the seeker under test. A collimated image also simplifies calculation of effective irradiances at the seeker.

The STS produces a collimated target image by placing an E-O source in the focal plane of the primary mirror. In order to accurately measure the effects of RFI/EMI testing, the seeker must be operated against a moving target, whose position and velocity are known precisely. Apparent target motion is achieved in the STS by a circular rotation of an E-O source. A servo-controlled motor drives an off axis rotating aperture and both target position and rate are sensed through an optical shaft encoder. Various size pinholes can be fitted to the aperture to create different size targets. The apertures are illuminated by a variety of E-O sources which cover the spectrum from the visible to the far IR (8-14 μm wavelength). The energy from the sources is transferred via a rotating periscope which greatly reduces the required source diameter's dependence on scan angle.

3.0 Goals vs Actual Performance

At the end of the original study, a set of design goals was generated. During detailed design and breadboard construction, these goals were considered as if they were system specifications. The breadboard constructed and delivered meets or exceeds nearly all the critical design goals, as is shown by the measured performance summarized in Table I.

In nearly all cases, target scan angle and target angular subtense have the same effects on system configuration. These two quantities drive the focal plane periscope design. Combined with unvignetted spot size, they also determine the required primary mirror diameter. A compromise design of $\pm 1^{o}$ scan was reached. Small increases in scan angles would exact a heavy penalty in required mirror apertures, as well as less severe decreases in resolution. Larger target sizes would exact the same penalties as increased scan angles. In addition, larger target sizes would seriously complicate focal plane periscope design and would require custom EO sources or complex source optics.

The design goal for an unvignetted spot size of 4" at 24 feet (10.16 cm at 7.32 m) was to cover a minimum seeker aperture diameter of 2.5" (6.35 cm) plus allow working room. The system meets the minimum requirements at maximum range, but not the desired goal. However, workable spot sizes are achieved at more probable ranges.

Scan rate variability was specified as an absolute number with no qualifications. This number was derived from seeker track noise levels, and was intended to be applied to the minimum scan rate. This corresponds to a variability of 50% of the minimum scan rate. If applied to the maximum scan rate, this would indicate a 0.1% tolerence. This requirement was considered unnecessarily strict for the high rates. Instead a more reasonable value of $\pm$ 1% variability over the entire specified scan rate range was achieved with a servo-controlled motor. In addition, this provides a much better performance at the lower (and most critical) scan rates. Outside the specified range, a variability of $\pm$ 10% was observed.

Table I.

Characteristic	Goal	Design	Actual
Resolution	$\leq$1.0 mrad	$\leq$1.0 mrad ($\pm$1° scan) $\leq$2.0 mrad	$<$0.1 mrad [4" (10.2cm) optics, full aperture]
Scan angle	$\pm$1° with a Goal of $\pm$2°	$\pm$1° all working specs $\pm$1.5° relaxed requirements	same as design
Spot size	4" @ 24 ft. (10.2cm @ 7.32m)	2.5" @ 24 ft. (6.4cm @ 7.32m) 3.0" @ 21.8 ft. (7.6cm @ 6.64m) 4.0" @ 17.9 ft. (10.2cm @ 5.46m)	same as design
Max. target size	2.0°	0.5°	same as design
Min. target size	1.0 mrad	1.0 mrad	0.6 mrad
Target position accuracy	0.8 mrad	Est. 2.0 mrad	0.92 dynamic $\leq$0.1 static
Target position output accuracy	----	0.767 nominal	0.92 dynamic
Max. scan rate	30°/sec	30.7°/sec	same as design
Min. scan rate	1.2 mrad/sec	0.428 mrad/sec. w/ output 0.360 mrad/sec. w/o output	0.11 mrad/sec. all w/ output
Scan rate variability	0.6 mrad/sec. (i.e. 50% of Min. rate)	Max. 1% over entire range	$\pm$1% spec $\pm$10% elsewhere

Table I. (Cont.)

Characteristic	Goal	Design	Actual
Scan rate output	Digital	16 bit word, Elapsed time per quad	16 bit E.T. for one rev to 1/128 rev
Scan rate readout	Panel Meter	Motor rpm, 3 1/2 Digit display	same as design
Total weight	500 lbs. (227 kg)	500 lbs. (227 kg)	475 lbs. (216 kg) w/o covers 671 lbs. (305 kg) w/ covers
Irradiance (Max) 1 deg target 0.6 to 0.9 μm	8×10^{-5} w/cm^2	10^{-5}	7.7×10^{-6} w/cm^2*
0.4 to 0.7 μm	8×10^{-5} w/cm^2	10^{-5}	4.2×10^{-6} w/cm^2*
1.5 to 3.0 μm	10^{-7} w/cm^2	----	1.8×10^{-5} w/cm^2 (2.19 to 2.31 μm)
3.5 to 5.5 μm	4×10^{-7}	----	1.5×10^{-5} w/cm^2 (3.73 to 3.90 μm)
8.0 to 13.5 μm	10^{-9}	----	8.2×10^{-7} w/cm^2 (11.2 to 11.4 μm)

*measured from 1 mrad target; values corrected to 1 degree target for comparison.
Max. target size is 0.5 degrees.

The total system weight with the dust covers was slightly over the design goal. This was not considered a serious drawback, as the cover sections were each easily two man portable. The total weight less covers was 25 pounds (11.34 kg) under maximum design goal.

Maximum irradiances all exceeded the design goals except for the visible bands. However, direct observation determined that the images were extremely bright and should be perfectly adequate targets.

Target position accuracy was slightly worse than the design goal (15%) for a dynamic target but is a factor of 10 better in the static case. This indicates the major error source is in the focal plane motion, probably due to the accuracy of the drive gears. However, the gears used were the best available without resorting to exotic custom gears with long lead times and prices over $20K each.

All other goals including static resolution, minimum target size, scan rate dynamic range, scan rate outputs and IR irradiances exceed design goals.

4.0 Setup and Operation

4.1 Initial Setup Procedure, Figure 4.1.1

1. Assemble optical rails.
2. Mount focal plane assembly base plate.
3. Loosely mount focal plane assembly.
4. Loosely mount primary mirror, do not mount flat fold mirror at this time.
5. Adjust primary to focal plane distance and focal plane tilt.
6. Align image center to sight marks at flat mirror location (w/o flat).
7. Mount flat.

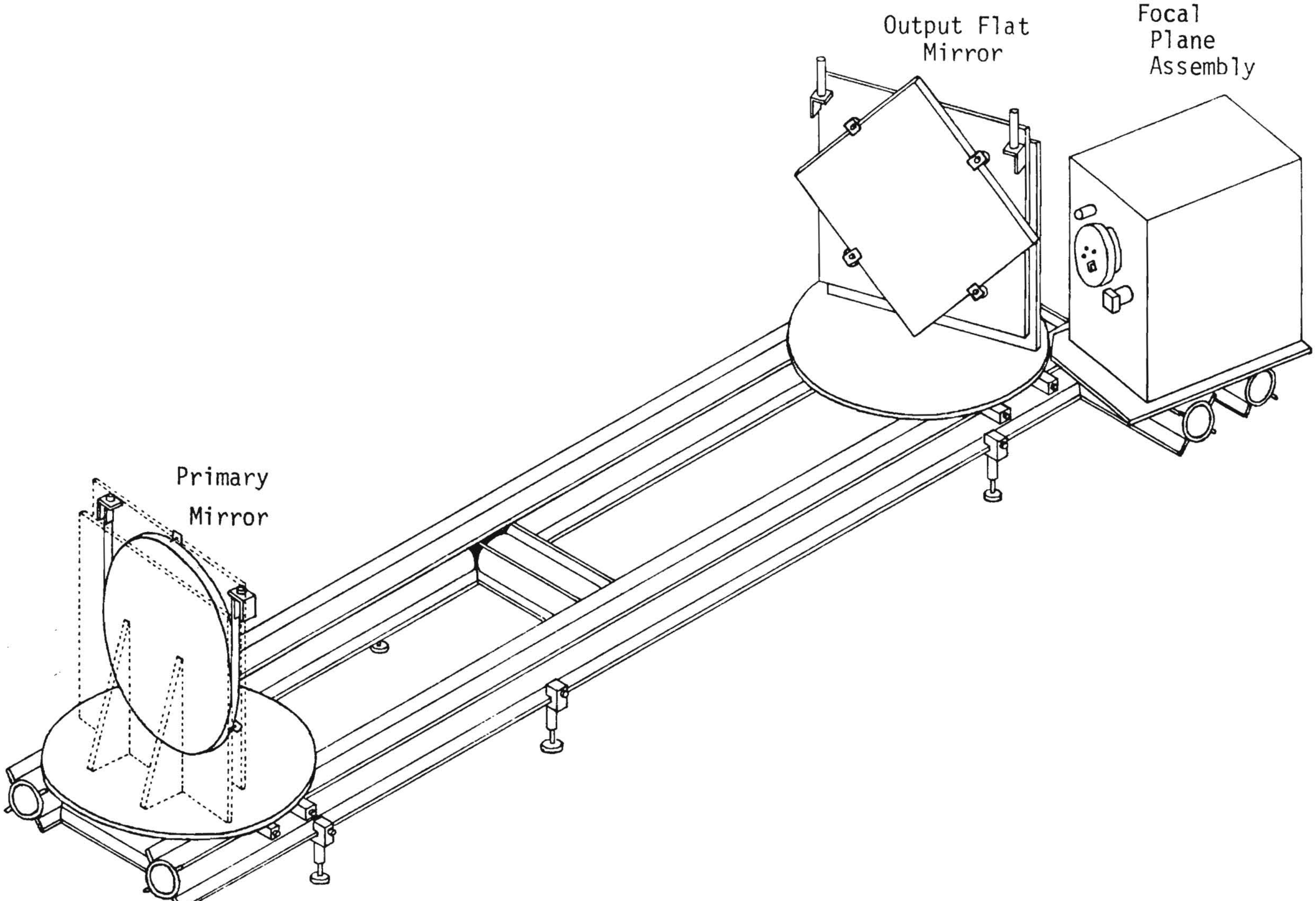

Figure 4.1.1. System Setup.

8. Install alignment scope in focal plane assembly.
9. Position crosshairs on seeker by moving flat. System is aligned optically.
10. Connect motor cable to electronic rack.
11. Connect encoder cable for digital outputs.
12. Connect arc lamp cable if required.
13. Connect blackbody cable if required.
14. Install dust covers, if desired.

4.2 Operation Procedure

1. Check system alignment. (See 4.1 and Hints 2-5,8).
2. Install alignment scope in focal plane assembly (FPA).
3. Position crosshairs on seeker by moving flat mirror.
4. Remove scope and install periscope mirror assembly.
5. Install proper target sized pinholes - be careful not to damage flat black coat.
6. Install light shield, if necessary.
7. Set scan angle.
8. Install appropriate source. See Source Installation.
9. Set motor control potentiometer for zero speed (full CCW).
10. Set arc lamp supply control to lowest setting (full CCW).
11. Turn on motor power for motor and encoder/decoder operation.
12. If used, turn on arc lamp supply power.
13. If used, turn on blackbody controller and set using calibration tables. This should give an approximate setting.

14. Acquire target with seeker.
15. For best accuracy, actual seeker response to blackbody input should be used. Used measured seeker responsivity.
16. Set motor speed to give desired scan rate. Operational setup complete.

4.3 Source Installation, Figure 4.3.1

4.3.1 Arc Lamp

1. Remove FPA cover.
2. Remove any other source and associated hardware.
3. Adjust shelf to top position.
4. Place arc lamp housing behind gear assembly. Three filter holding rods should be centered around periscope input aperture, with about 1/16" (2 mm) clearance from the gear.
5. ND filters fit in rods between moveable collar and housing. Install if required.
6. Connect cables.
7. Replace FPA cover.

4.3.2 Blackbody

1. Remove FPA cover
2. Remove any other source and hardware
3. Adjust shelf to bottom position.
4. Mount ZnSe lens and holder. Lens end fits into periscope input aperture. Adjust holder so that it is concentric with the aperture.

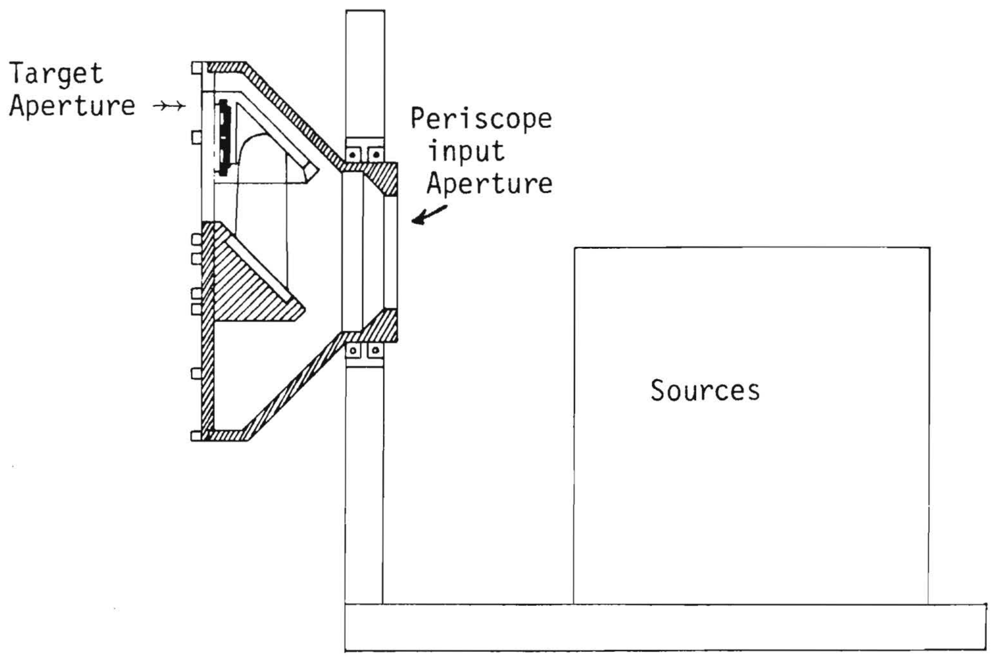

Figure 4.3.1. Focal plane assembly.

5. IR filters slide into slot at back of lens holder.
6. Connect clabes.
7. For accurate temperature control, immerse thermocouple reference junction in 0^oC ice bath. See Blackbody Manual.

4.3.3 Laser

1. Remove FPA cover.
2. Remove other sources.
3. Adjust shelf to middle position.
4. Assemble laser according to manufacturer's instruction.
5. Replace cover.

4.4 Dust Covers

There are three large dust cover segments and one small cover for the focal plane assembly, Figure 4.4.1. The three large covers are labeled as follows:

Cover A: Largest cover, which covers the primary mirror end, left end when viewed from output side of flat. Open edge is straight. Cover A requires two people to handle.

Cover B: Center, U-shaped section, with output window. Requires bottom braces. Can be handled by one, but two is preferable.

Cover C: Left end cover goes over output flat and focal plane assembly. Can be handled by one.

4.4.1 Installation

1. Complete assembly of optics, rails and focal plane assembly.
2. Position assembly on chamber platform.
3. Place cover A over primary mirror end and note location of open edge.
4. Slide cover A back approximately 3 to 4 inches (8 to 10 cm).
5. Carefully slide cover C over rails from output flat end. Use extreme care as clearances are very tight. Also, be sure cables are kept clear during installation.
6. Locate cover B edge at spot determined in step 3.
7. Install angle braces at bottom edges of both openings of cover B.
8. Lift cover A up at both ends and locate edge of A in channel of B. Lower cover A.
9. Align edges of A in side channels.
10. Lock three handles and two catches. Handles should be adjusted to provide a firm alignment of the two pieces.
11. Repeat steps 8 through 10 for cover C.
12. Cover C is designed for easy access to output flat and focal plane assembly.

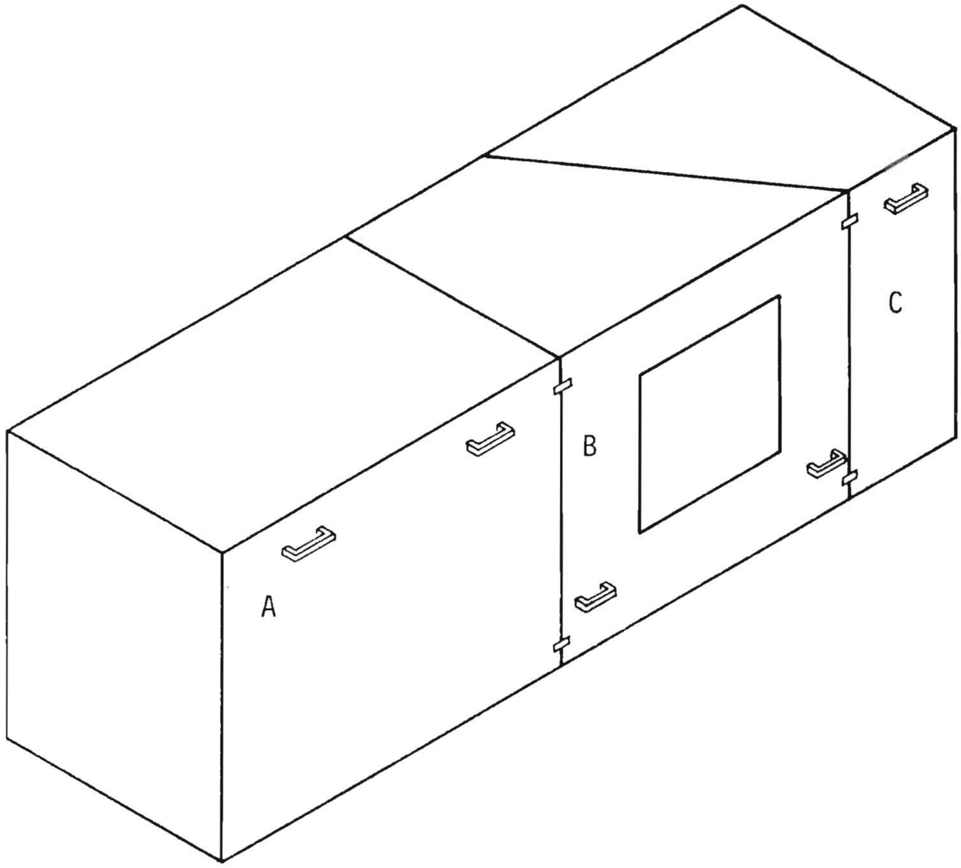

Figure 4.4.1. Dust covers

4.4.2 Removal

1. Release all latches and handles.
2. Remove cover C by lifting up, then away from B.
3. Lift both ends of cover A up, then away from cover B.
4. Remove cover B braces.
5. Slide cover B towards primary and remove when clear. Cover B may also be slid over output end, but extreme care should be used, as clearances are very tight. Also cables should be kept clear during cover B removal.

4.5 Warnings and Hints

1. Extreme care must be taken to avoid any contact with the reflective coatings on the main mirrors, as they are easily marred.
2. Assembly optical rails, using scribe marks and lettered codes. The only critical placement is the distance from the primary mirror to focal plane.
3. This distance should be 78.75" $\pm$ 0.25" (2.0m $\pm$ 0.6cm) from the center of the primary to the pinhole aperture plane. Since it is NOT recommended to place any measuring device against the mirror surface, the distance can be computed from the edge of the primary to its mount. The distance from the focal plane to a convenient point on the assembly base can be calculated. The primary to focal plane distance can be calculated and set with a tape measure. This is sufficient accuracy for a good focus. See Hint 8 for focusing procedures with an autocollimator. Loose insertion of the front locking screw on the focal plane assembly will facilitate later alignment.

4. Carriers on optical rails are sometimes difficult to remove or adjust. This can usually be alleviated by turning clamp screws as far in as they will go without forcing. Apply outward pressure on clamping feet as clamp screw is released.
5. Quick assessment of optical alignment can be done by eye throughout most of this system. The current location of the optical line of sight can be determined by looking into the system and changing the position of the eye until the images of the circular focal plane plate and the primary mirror are concentric. The accuracy of the alignment can be improved by moving backward or forward until the relative sizes of the images are nearly the same. The human eye and brain are very good at comparing nearly concentric images.
6. Large optics can be transported while still in mounts if extreme care is used. If possible, two persons should handle as the the combination is very heavy.
7. Light dust and small scratches in optical surfaces only affect appearance, with little or no effect on performance. Therefore it is better to leave optics a little dirty than risk more significant damage by cleaning too often. If plastic dust bags are used, care should be taken when installing or removing them from optics, as they may scratch optical surfaces.

8. To set focus using autocollimator.
   a. Set collimator to exact infinity focus (usually 100% compensation).
   b. Locate pinhole with collimator.
   c. Adjust focal plane assembly to primary distance until sharp image of pinhole is achieved.
   d. Primary is focused.
9. Proper alignment of blackbody, ZnSe lens and collimator <u>cannot</u> be determined visually by observing through aperture and focal plane periscope. The observations are misleading and should NOT be used to judge alignment. Alignment can only be checked by observing scan from seeker location to insure that no vignetting is occuring.

5.0 System Calculations

This section presents the equations which are necessary to operate the STS. Each section has a brief explanation of the origin and/or theory of each set of equations.

5.1 Target Motion

5.1.1 Target Angles vs Focal Plane Distances

The amplitude of target motion or scan angle is calculated easily from simple geometry, Figure 5.1.1.1. The focal plane distance, d, is defined as the distance of the pinhole center from the center of the focal plane plate. The scan angle, Θ_s, is the arctangent of d, divided by the primary focal length, f.

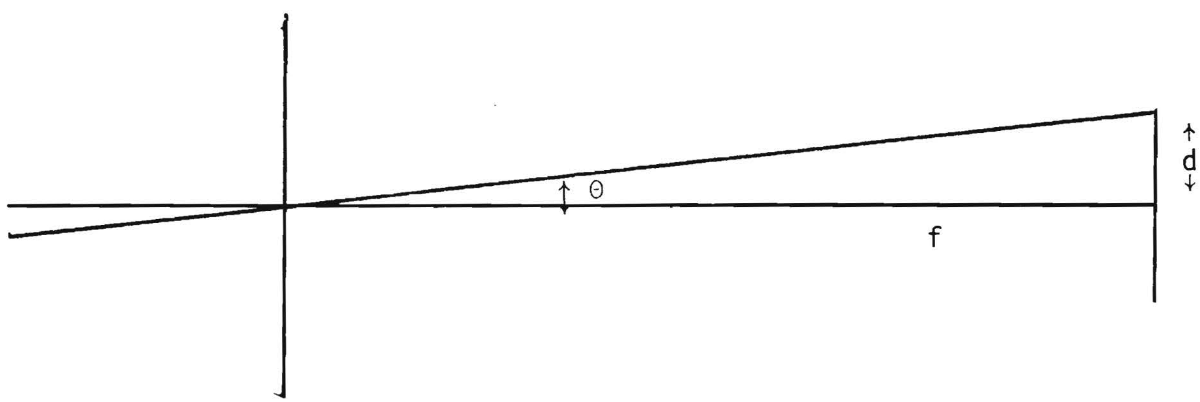

Figure 5.1.1.1. Focal plane distances vs. angle.

$$\Theta_s = \mathrm{Atan}\ (d/f) \qquad (1)$$

The scan angle is a radial measure, thus the total target motion is $\pm\ \Theta_s$.

It is very convenient to work in the metric system, since primary focal length of 78.75" equals exactly 2 meters. with the approximation

$$\tan \Theta \simeq \Theta \qquad (2)$$

then equation 1 becomes

$$\Theta_s = d/f \qquad (3)$$

Thus if d is in millimeters, and f is in meters, then Θ_s is in milliradians. More succinctly:

$$\Theta\ (\mathrm{mrad}) = \frac{d(\mathrm{mm})}{2} \qquad (4)$$

Equations 1,3 and 4 can also be used to calculate the target angular subtense, as all the relations are exactly the same.

Two conversion factors which are helpful to remember this process are:

1 inch = 25.4 mm
1 deg = 17.45 mrad.

5.1.2 Target Velocity vs Motor Speed

The three digit display on the STS indicates the motor speed in thousands of rpm (i.e. a meter reading of .634 = 634 rpm, 1.21 = 1210 rpm). This motor drives the focal plane through a set of gears, with the focal plane running slower than the motor by a factor of 25.71:1. The target velocity is defined as the tangential velocity of the target in its circular scan. Thus the target velocity, V, is a function of both the angular rate of rotation and the target scan angle, Θ_s.

$$V_T(\text{deg/s}) = \frac{2\pi\ V_m(\text{rpm})\ \Theta_s(\text{deg})}{G\ 60(\text{Hz/rpm})} \tag{5}$$

$$G = \text{gear ratio} = \frac{120\text{x}198}{21\text{x}44} = 25.71 \tag{6}$$

Θ_s= scan angle; V_T is in same units as Θ_s per second.
V_m= motor velocity

Other convenient formulas:

$$V_m(\text{rpm}) = \frac{V_T(\text{deg/s})\ G\ 60}{2\pi\ \Theta_s(\text{deg})} \tag{7a}$$

$$V_m(\text{rpm}) = \frac{V_T(\text{deg/s})\ G}{6\ \Theta_s(\text{rad})} \tag{7b}$$

$$= \frac{V_T(\text{rad/s})\ 180\text{x}60}{\pi^2\ \Theta_s(\text{deg})} \tag{7c}$$

$$= \frac{V_T(\text{mrad/s})\ 14.07}{\Theta_s(\text{deg})} \tag{7d}$$

5.1.3 Target Position vs Counts

As part of the STS electronics rack, there are two digital outputs generated by the STS. The first is a 16 bit word which contains the target position with respect to the zero mark. This mark can be referenced to any particular physical orientation by loosening the set screw on the gear which drives the optical shaft encoder. The encoder can then be turned independently of the focal plane gears to align the physical and optical zero marks. The set screw is then tightened to maintain this reference.

The encoder is 13-bit serial with a zero reference. The STS electronics maintains an up/down count of the serial pulse string until reset by the zero reference mark. If the output counts down, the motor should be reversed. This is accomplished by swapping the two leads on the back of the motor with each other, then swapping the two leads on the front with each other. The fraction of a revolution from the zero mark is

$$\varepsilon = \frac{8192}{\text{PCNTS}} \qquad \text{(8a)}$$

PCNTS = position counts

$$P_T = 2\pi\varepsilon \quad \text{(radians)} \qquad \text{(8b)}$$

$$= 360\varepsilon \quad \text{(degrees)} \qquad \text{(8c)}$$

5.1.4 Target Velocity vs Elapsed Time

The second digital output is elapsed time. The elapsed time is for a fraction of a revolution which is hardware selectable from once per revolution to 128 times per revolution. Each reset pulse triggers a counter on a 2KHz clock which provides a number of counts, ECNTS, proportional to the elapsed time over that interval.

The velocity of the target can then be calculated by

$$V_T(\text{deg/s}) = \frac{2\pi\ f_c\ \Theta_s(\text{deg})}{\text{ECNTS}\ Q} \qquad (9)$$

f_c = clock freq = 2000 $\sec^{-1}$

Q = # updates per revolution (1-128)

ECNTS = output counts

5.2 Irradiance

5.2.1 Planck's Law

Planck's Law describes the spectral radiant emittance of a perfect blackbody radiator as a function of wavelength and temperature.

$$W_\lambda(\lambda,T) = \frac{C_1}{\lambda^5\left(e^{C_2/\lambda T}-1\right)} \qquad (10)$$

where C_1 = 37405 $W\mu m^4/cm^2$

C_2 = 14387.9 μm °K

when T = blackbody temperature is in degrees K

λ = wavelength in μm

W = spectral radiant emittance $W/cm^2/\mu m$

One must remember that the blackbody calibration curve in the blackbody operating manual provided with the STS is in degrees centigrade and that

$$T(^{o}K) = T\ (^{o}C) + 273 \qquad (11)$$

To find the total radiant emittance, one usually approximates a system's spectral transmittance by a rectangular bandpass with limits at the half-power wavelengths. The radiant emittance is given by

$$W = \int_{\lambda_1}^{\lambda_2} W\ (\lambda,\ T)\ d \qquad (12)$$

where W is in W/cm^2

λ_1, λ_2 = Band limits; usually half power points.

5.2.2 Blackbody Irradiance

For any seeker which falls within the unvignetted spot, the irradiance at the seeker dome is independent of range (up to spot limits, see Sec 5.3). The effective irradiance,

$$H_{eff} = \tau_o \tau_f \left(\frac{\Theta}{2}\right)^2 W \tag{13}$$

where τ_o = transmission of collimator optics
= 0.92 without ZnSe lens
= 0.75 with ZnSe lens

τ_f = peak transmission of filter, Table II.

W = radiant emittance for blackbody over filter bandpass. (λ_1 to λ_2)

Θ = target angular subtense (radians)

H_{eff} is in W/cm^2.

5.2.3 Arc Lamp Irradiance

The arc lamp source can be treated as a blackbody radiator, after the diffusing glass and lamp geometry have been taken into account. The equivalent blackbody temperature is given by

$$T(^oK) = 1347 \quad V^{0.3319} \tag{14}$$

Where V is the arc lamp supply voltage reading. The effective irradiance is then given by

$$H_{eff} = \frac{\Theta^2 W 10^{-Nd}}{4493} \tag{15}$$

Table II. STS filters

Center λ (μm)	Bandpass Limits (μm)		Transmission (τ_f)
	λ_1	λ_2	
For 1.5 to 3.0 μm			
2.24	2.19	2.31	0.59
For 3.5 to 5.5 μm			
3.82	3.73	3.90	0.62
For 8.0 to 13.5 μm			
11.32	11.17	11.40	0.52

Θ = target angular subtense (radians)

W = radiant emittance for temperature over desired spectral range.

Nd = neutral density filter optical density for no filter Nd = 0.0, i.e. $10^{-0} = 1.0$

This formula is good only to about 1.1 μm. Beyond this point, a relative transmission factor must be measured and included to account for the increase of opacity with wavelength of the diffusing glass and coating.

5.2.4 Laser Irradiance

The effective irradiance for a laser can be calculated if the effective radiant emittance, W_{laser}, of the diffuse laser source is known. It is given by:

$$H_{eff} = \tau_o \left(\frac{\Theta}{2}\right)^2 W_{laser} \qquad (16)$$

Where $\tau_o = 0.92$

Θ = target angular subtense

5.3 Unvignetted Spot Diameter

In order to use the irradiance equations of the previous section, the seeker must be completely inside the converging cone of collimated light, Figure 5.3.1. Figure 5.3.2 defines some of the parameters which determine the spot diameter, D_s.

$$D_s = D_c - 2s \tan \Theta \tag{17a}$$

$$\Theta = \Theta_s + \Theta_T/2 \tag{17b}$$

$$S = C+E$$

$$E = \sqrt{(R+A)^2 + B^2} \tag{17d}$$

D_c = diameter of collimator mirror = 16 in. = 41 cm

Θ_s = scan half angle

Θ_T = target angular subtense

S = total distance collimater to seeker

C = primary to output flat distance = 72 in. = 1.8m

A = distance from front of stage to output mirror center

B = distance from antenna centerline to output mirror center

R = distance from front of stage to seeker aperture

Several other convenient formulae:

$$S = \frac{D_c - D_s}{2 \tan} \tag{18}$$

$$\Theta = \text{Atan} \frac{D_c - D_s}{2S} \tag{19}$$

$$\phi = \text{Atan} \frac{B}{R+A} \tag{20}$$

ϕ = angle between centerline and line of sight to STS output mirror

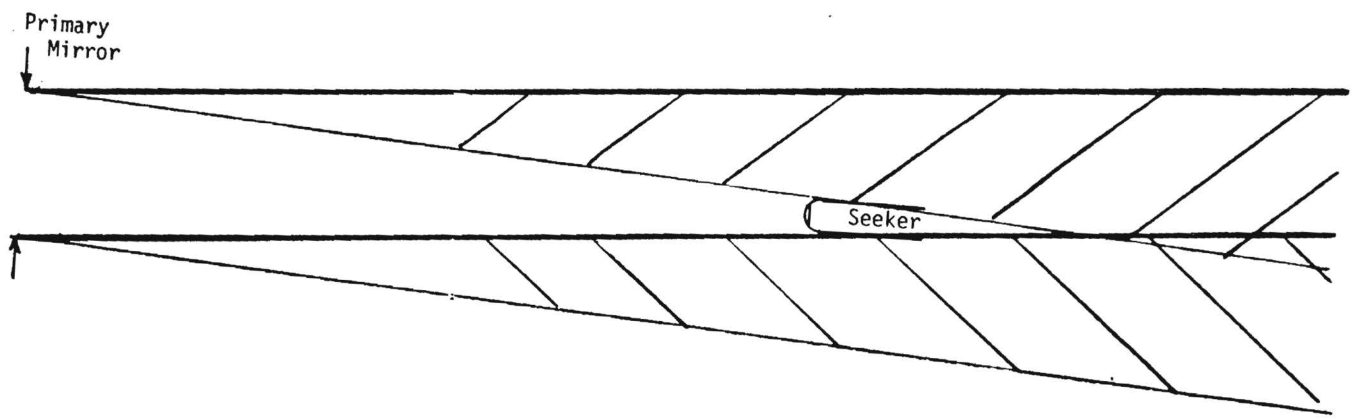

Figure 5.3.1. Unvignetted spot diameter.

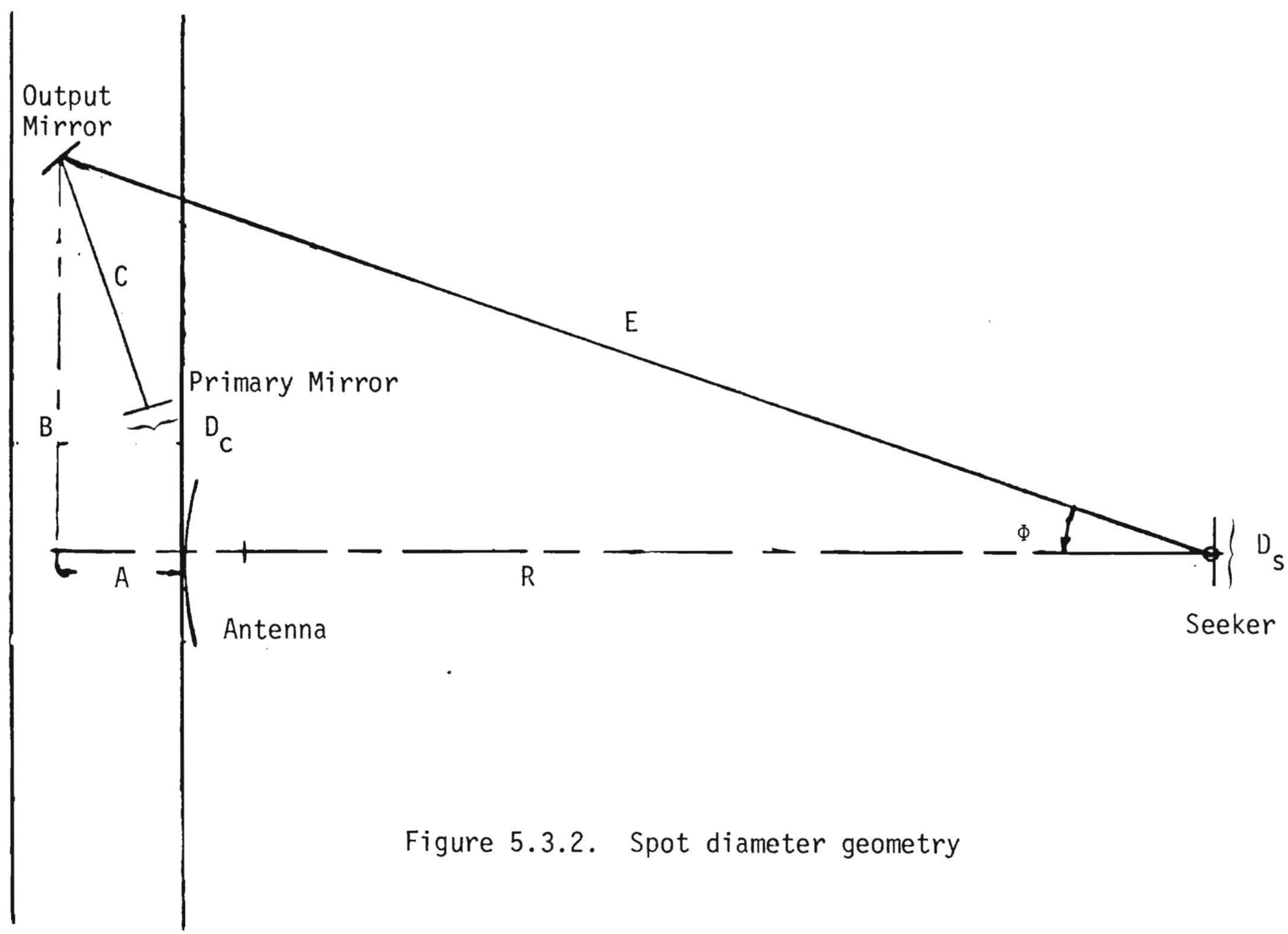

Figure 5.3.2. Spot diameter geometry